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How will greenhouse gas emissions from motor vehicles be constrained in China around 2030?

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HIGHLIGHTS

- We build a projection model to predict vehicular GHG emissions on provincial basis.
- Fuel efficiency gains cannot constrain vehicle GHGs in major southern provinces.
- We propose an integrated policy set through sensitivity analysis of policy options.
- The policy set will peak GHG emissions of 90% provinces and whole China by 2030.

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ABSTRACT

Increasing emissions from road transportation endanger China's objective to reduce national greenhouse gas (GHG) emissions. The unconstrained growth of vehicle GHG emissions are mainly caused by the insufficient improvement of energy efficiency (kilometers traveled per unit energy use) under current policies, which cannot offset the explosion of vehicle activity in China, especially the major southern provinces. More stringent polices are required to decline GHG emissions in these provinces, and thereby help to constrain national total emissions. In this work, we make a provincial-level projection for vehicle growth, energy demand and GHG emissions to evaluate vehicle GHG emission trends under various policy options in China and determine the way to constrain national emissions. Through sensitivity analysis of various single policies, we propose an integrated policy set to assure the objective of peak national vehicle GHG emissions be achieved around 2030. The integrated policy involves decreasing the use of urban light-duty vehicles by 25%, improving fuel economy by 25% by 2035 comparing 2020, and promoting electric vehicles and biofuels. The stringent new policies would allow China to constrain GHG emissions from road transport sector around 2030. This work provides a perspective to understand vehicle GHG emission growth patterns in China's provinces, and proposes a strong policy combination to constrain national GHG emissions, which can support the achievement of peak GHG emissions by 2030 promised by the Chinese government.

1. Introduction

The Chinese government has pledged to peak its greenhouse gas (GHG) emissions around 2030 in the joint announcement with the US in November 2014. In the U.S.-China Joint Announcement on Climate Change, China agreed to peak its CO_2 emissions around 2030 while striving to peak early, and boost the share of non-fossil fuel energy to around 20%. The peak emission goal requires national emissions reach the maximum level around 2030 and start to decrease since then. All GHG emission sectors in China need stringent control, while increasing emissions from

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road transportation endanger the national goal. China has experienced a 23 times increase in the number of vehicles since 1990. Consequently, CO_2 emissions from road transportation in China increased by 7.7 times between 1990 and 2013, while average increase in other economic sectors was only 5 times (Multi-resolution Emission Inventory of China, http://www.meic-model.org). As vehicle sales in China have become the largest in the world, the total vehicle stock is projected to grow fast in next decades [1–3]. The predicted explosive growth of on-road vehicles will consume massive fuel and emit large amount of GHGs. Constraining vehicle GHG emissions will definitely become a big challenge for China.

International experience suggests road transport may be the most difficult sector to reduce GHG emissions. For example, in the EU, transport is the only major sector with rising GHG emissions; and in the US, road transport is experiencing a much slower declining rate for GHG emissions than the other sectors. Since the continued growth of vehicle emissions endangers global or regional climate targets, many studies proposed stringent measures to constrain vehicle emissions [4–6]. Researchers expressed that China could peak its total CO_2 emissions around 2030, while the transport sector may continue the growth [7,8]. Many studies have projected the future energy use and GHG emissions of road transportation in China. They provide valuable information on vehicle stock growth and survival patterns [2,3], future energy use and emission trends [1,9–13], and effects from electric vehicles and alternative fuels [14–23].

These studies are all conducted at the national level. While provincial disparities of China's transport sector are being analyzed more frequently in recent years, very few researches focus on provincial emission projection. Literatures show regional inequity in vehicle growth and fleet turnover patterns is considerable and requires provincial oriented analysis. Using national average parameters for projection may lead to either under- or over-estimation of emissions for different provinces due to uneven regional development [24–27].

Lack of provincial-level emission analysis and projections may lead to poor implementation of national policy. It is particularly important for China to disaggregate the national target into provinces [28–32] to guarantee local efforts are in line with the national goal and track the processes for carbon reduction [33]. It requires the research areas switch from national scale to provincial scale, in order to show a detailed picture for regional disparities and provide better targeted policy suggestions. Previous researches resolve the provincial energy intensities and efficiencies [34–36], the diversity of GHG reduction potentials and costs [37–39] and the benefit of inter-provincial emission trading system [40,41]. However, provincial-specific projection for transport sector is absent. The national total projections cannot help analyze provincial driving forces and allocate national GHG emissions allowance over provinces, which makes it difficult to implement regional oriented policies. A provincial-level study evaluating the development of on-road vehicle GHG emissions towards the national peak and ways of securing their subsequent decline is urgently needed. This work tries to resolve the gap between national GHG target and provincial accountability for reduction efforts in China's transport sector.

In this paper, we project provincial vehicle activity growth in China from 2010 to 2035 and propose strategies to constrain the national total emissions by 2030 and decline the emissions afterwards. We build fleet turnover models for each province to project provincial-level vehicle growth, energy demand and GHG emissions through 2035. Using such model, we evaluate the effects of different policy options and an integrated policy set is finally proposed to ensure peak GHG emissions by 2030. Our objectives are to improve the resolution of vehicle GHG emission projection in China and provide better understanding of the roadmap towards national peak emissions.

2. Methodology and data

2.1. General methodology

Vehicular energy use and GHG emissions are determined by total vehicle numbers, vehicle age distribution, annual distance travelled, fuel consumption rates and carbon intensity of the fuel. Tank-to-wheels (TTW) fuel consumption is calculated at first, and then is multiplied by carbon intensity of the fuel to get TTW GHG emissions. Well-to-wheels (WTW) energy use and GHG emissions are converted from the TTW fuel use on the basis of WTW energy-use intensity and GHG-emission intensity [11]. The reason of WTW analysis is that some polices such as electric cars and biofuel blends transfer emissions from tailpipe to upstream, which requires the whole life cycle analysis to evaluate the total emissions change.

For each province, TTW fuel consumption and GHG emissions are estimated from 2010 to 2035 by Eqs. (1) and (2):

$$Fuel_k = \sum_i \sum_j (VP_i \times X_{i,j,k} \times VKT_{i,j,k} \times FC_{i,j,k} \times density_k) \quad (1)$$

$$Emis_{TTW} = \sum_k (Fuel_k \times EF_k) \quad (2)$$

where i represents vehicle types, including private cars owned by all urban residents (denote as urban PCs) and rural residents (denote as rural PCs), urban motorcycles (urban MCs), rural motorcycles (rural MCs), commercial light-duty vehicles (commercial LDVs), buses, light-duty trucks (LDTs) and heavy-duty trucks (HDTs); j represents vehicle age in years; k represents fuel type; VP_i is the number of vehicles of type i; $X_{i,j,k}$, $VKT_{i,j,k}$ and $FC_{i,j,k}$ represent age distribution (share of vehicles in age class j), annual distance traveled (km) and fuel economy (L km^{-1}) for vehicle type i using fuel k at age j; $density_k$ is the density of fuel k (kg L^{-1}); EF_k is the CO_2 emission factor (g kg^{-1}) (other GHG emissions are ignored in the TTW stage because of their few amount); *Fuel* and $Emis_{TTW}$ are TTW fuel consumption (kg) and CO_2 emissions (g), respectively. Electric motorcycles are excluded from this work because the method of refining spatial resolution of vehicle activity projection from nation to province is not applicable given the fact that the growth functions of electric motorcycles are not clear due to lack of data.

Provincial WTW energy use and GHG emissions are then calculated using Eqs. (3) and (4):

$$Energy_E = \sum_k (Fuel_k \times EI_{k,E}) \quad (3)$$

$$Emis_{WTW} = \sum_k (Fuel_k \times GI_k) \quad (4)$$

where E represents energy source (coal or petroleum); $EI_{k,E}$ represents WTW energy intensity of energy E for fuel k (kg kg^{-1}); GI_k represents WTW GHG emission intensity for fuel k (g kg^{-1}); *Energy* and $Emis_{WTW}$ are WTW energy use (kg) and GHG emissions (g), respectively.

As presented in Eqs. (1)–(4), *VP*, *X*, *EF*, *VKT*, *FC*, *EI* and *GI* are key parameters in this work. *VP* and *X* are modeled for each province using methods described in Section 2.2. TTW CO_2 emission factors, *EF*, are calculated using fuel carbon intensity multiplied by 3.67 (ratio of molecular weight of CO_2 to carbon). National average *VKT* and *FC* are derived from simulation results of the Fuel Economy and Environmental Impact (FEEI) model [42–44], for which the data source and projection method are briefly described